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(54) **HIERARCHICAL MULTIPLE-LEVEL CONTROL OF ADAPTIVE COOLING AND ENERGY HARVESTING ARRANGEMENTS FOR INFORMATION TECHNOLOGY**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

4,467,611 A * 8/1984 Nelson et al. 62/3.3
4,748,676 A 5/1988 Miyagawa
(Continued)

FOREIGN PATENT DOCUMENTS

EP 0 574 213 B1 12/1993

OTHER PUBLICATIONS

Dulberg, M. S., et al. An Imprecise Mouse Gesture for the Fast Activation of Controls, IOS Press, Aug. 1999, [online] [retrieved on Jul. 9, 2013] URL: http://www.csc.ncsu.edu/faculty/stamant/papers/interact.pdf.gz, 10 pgs.
(Continued)

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(57) **ABSTRACT**

A system for adaptive cooling and energy harvesting comprising at least one thermoelectric device capable of acting as a thermoelectric cooler and as a thermoelectric generator, a hierarchical multiple-level control system, and electronics controlled by the control system and connected to the thermoelectric device. The electronics selectively configure the thermoelectric device in at least in a thermoelectric cooler operating mode and in a thermoelectric generation operating mode. The thermoelectric device can incorporate quantum-process and quantum-well materials for higher heat transfer and thermoelectric generation efficiencies. The invention provides for thermoelectric devices to additionally operate in temperature sensing mode. The hierarchical control system can comprise a plurality of control system, each of which can operate in isolation and can be interconnected with additional subsystems associated with other hierarchical levels. The hierarchical control system can comprise linear (additive) control, bilinear (additive and multiplicative) control, nonlinear control, and hysteresis.

20 Claims, 67 Drawing Sheets